Testing Device For Tensile Test Based on Arduino

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Abstract: - An experimental device was proposed to determine the elastic tensile and compressive modulus E_t and E_C of materials simultaneously through the deformation and displacement measurement in the split test, which is based on study of disk loaded by a pair of radial opposing forces. The electronics controlling experimental device used Arduino platform. Based on the proposed test theory, there is method based on comparison of Finite element model and data obtained from modified Brazilian test. The modification of Brazilian test is based on use curved jaw. Curved jaws are necessary for fulfillment requirement of sample breaking in the middle. These condition is a necessary condition for determining traverse tensile strength. The exact description of jaws curvature is necessary for calculation of elastic modulus, because the deformation of jaws and stone sample affects results of determination of elastic modulus. The big problem description deformation in the area of contact is probably a caused that the change in shape of a cylinder in contact, is due not only elastic deformation but straight graining and loss of material. Three groups of experimental data are used to validate the proposed test theory. The analysis indicates that the estimated E_t and E_c of materials have high reliability when measured vertical displacement of jaws and rock sample i.e changes in diameter of sample simultaneously. The measurement error of displacement results in that the estimated E_t and E_c of materials follow the changes in the radius of the cylindrical contact. The validation works indicate that the proposed test method is feasible and liable and is convenient to determinethe E_t and E_c of materials simultaneously through the simple indirect tension test. This device was developed as part of Master Thesis.

Key-Words: - Experimental device, Elastic modulus, Arduino controller, Tensile loading, Cylindrical specimen, Testing stone

1 Introduction

Hence, the Brazilian test is widely used as the standard testing method to obtain a value for the uniaxial tensile strength σ_{t0} because of the simplicity of specimen preparation and its execution [1–8]. A cylindrical specimen is uniaxially compressed in radial direction to induce tensile stresses perpendicular to the loading direction. The measured failure load and the geometry of the Brazilian test specimen serve as an input for calculating the Brazilian Tensile Strength σ_{BTS} which is generally taken representative for the tensile strength of the material [1,3,5]. Theory predicts the highest tensile stress that corresponds to a specific failure load P at the center of the cylindrical specimen, assuming this spot as origin of fracture [5]. Markides et al. [2] obtained closed form full-field solutions for the whole stress field in either plane stress or planestrain. However, the significance of these results is limited by Hudsonetal.'s finding [3] that the cracks do not necessarily initiate from the center. Additionally, the Brazilian test under estimates the uniaxial tensile strength [8], especially when the tested material has allow uniaxial compressive strength to uniaxial tensile strength ratio [7,8]. This suggests an influence of the uniaxial compressive strength (σ_{c0}) but this is not accounted for in the determination of σ_{BTS}. The obtained value for this tensile strength depends also on the contact conditions between specimen and jaws [7]. Some authors [6] pointed out that the tensile stresses can only be determined by a three-dimensional analysis because of the influences of the tensile stresses in the contact region. However, few investigations have been performed on three-dimensional (3D) simulations [6,7,8] but most calculations and analyses have been performed for two-dimensional (2D) domains only [6]. Laboratory implementation of the Brazilian disc test and some open questions Concerning the simulation of the boundary conditions prevailing along the disc-jaw or the disc-loading platen contact arc, the questions that are even today open, are related to the influence of a number of parameters on the stress field developed in the disc (both at its center and also in the vicinity of the disc-jaw contact area). These parameters are: (i) the length of the contact arc; (ii) the actual distribution of radial stresses along the contact arc; and (iii) A special configuration widely used nowadays is the flattened Brazilian disc proposed by Wang et al. (2004), whose scientific team contributes intensively also in the direction of improving the standardized cracked Brazilian disc test. Within the framework of the present study, attention will be paid to the role of the relative curvature of the jaw with respect to that of the disc and therefore the flattened Brazilian disc will not be considered. One of the proposed solutions is based on the use of jaws with radius. This case represents contact of two cylindrical surfaces under parabolically distributed load. The actual loads are not concentrated but distributed over finite arc cylinder.

2 Design of Experimental Device

The testing device is primarily intended for split tests of core samples. Weight of the device is approximately 2825 kg, see Fig. 1. The loading is performed by moving the lower grips upward. The lower grip is lifted by combined screw and wedge mechanism. Linear movement of the wedge is implemented by screw rotation. Maximal loading force is limited by 80 kN. Loading force is registered by logger from measuring bolt. Force data are imaged by data-logger display and can be recorded by a computer in digital form. Loading displacement data are obtained directly by measuring instruments based on optoelectronics sensors and by non-directly by counting of the loading screw revolutions, both types of data can be recorded by a computer in digital form. The device is controled by Arduino microcontroller and mechanical movement is caused by stepper motor. Interchangeable jaws with different ratios $R_{jaw}/R_{specimen}$ are installed in the testing machine. The custom written software is used to control the test equipment, see Fig. 2. The software stores the measured data from sensors to a file in *.txt format. The software can also draw a graph of the loading forces and deformations. The graph has a variable size, so it adjusts automaticaly to the measurement range. The user can also zoom for him an interesting part of the graph. This software allows calculation of tensile strength R_T, compressive strength R_C and flexural strength R_F using data obtained from the test device, without further operator intervention.

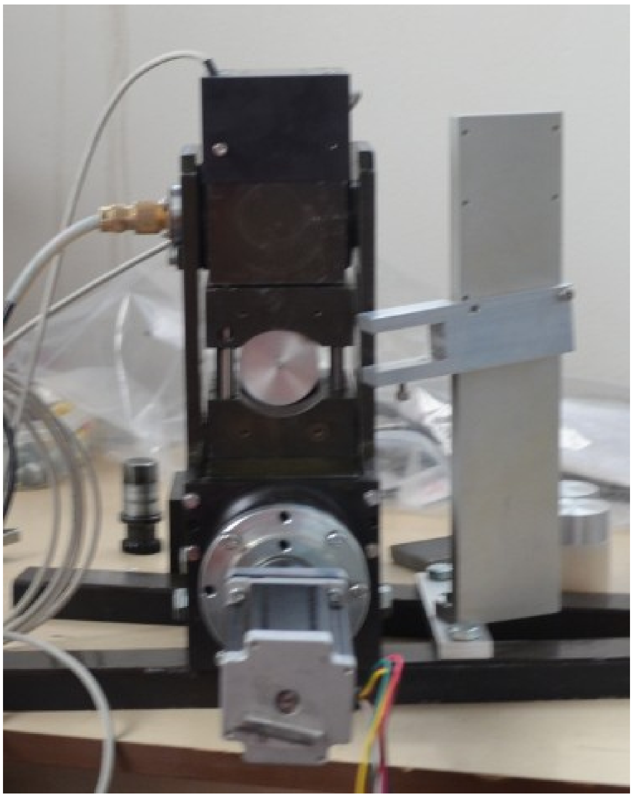

Fig.1 Testing device with cylindrical sample and stepper motor.

2 Split Test and Detrmination of Tensile Strength

Theoretical basis for the split test is analytical solution developed by Hondros for determination of elastic modulus and Poisson's ratio [1]. Complete stress solution linear contact between grips and specimen is expressed by three equations.

$$\sigma_x = \frac{2P}{\pi L}\left(\frac{\cos\theta_1 \sin^2\theta_1}{r_1} + \frac{\cos\theta_2 \sin^2\theta_2}{r_2}\right) - \frac{2P}{\pi DL}$$

$$\sigma_y = \frac{2P}{\pi L}\left(\frac{\cos^3\theta_1}{r_1} + \frac{\cos^3\theta_2}{r_2}\right) - \frac{2P}{\pi DL} \qquad (1)$$

$$\tau_{xy} = \frac{2P}{\pi L}\left(\frac{\cos^2\theta_1 \sin\theta_1}{r_1} + \frac{\cos^2\theta_2 \sin\theta_2}{r_2}\right)$$

where P is the linear load [N/m], L is the thickness of the disc and D is the diameter of specimen. The parameters Θ_1, Θ_2, r_1 and r_2 are geometrical characteristics of cylindrical specimen. That failure of cylindrical specimen is expected to initiate at the center of disc. The tensile strength R_T is expressed as

$$R_T = \frac{2P_{max}}{\pi LD} \qquad (2)$$

where P is the linear load [N/m], L is thickness of the disc, and D is diameter of the specimen. When using jaws with the radius, a more accurate solution proposed by Koukoulis can be used.

3 Determination of Elastic Modulus

In the case of the known relationship between displacement and load, other mechanical properties such as Young modulus can be determined. Estimation of Young modulus can be based on following relationships

$$A(\Delta x) = \Delta x \cdot F(\Delta x) \qquad (3)$$

where A is deformation work, Δx, resp x_i are the displacement, F is loading force. In the next equation S is instantaneous cross-section and W with subscription elastic is elastic energy.

$$S \cdot \sum_{i=1}^{i_{macx}} \left(F_{meas}(x_i) - F_{sim}(x_i)\right)^2 = \left(W_{elastic}\right) \qquad (4)$$

Two other indexes are *meas,* which means measured force and *sim* as simulated force.

$$\left(W_{elastic}\right) = \psi\left(E_{simulation}, \sigma_{simulation}\right) \qquad (5)$$

where E is Young modulus. Subscription indicates values measured directly by sensors. Subscription simulation indicates simulated values.

4 Determination of Elastic Modulus

Specimens were prepared from sandstone by core drilling. The specimens were made from sandstone, marlite and limestone. The specimens were obtained in dry condition. Diameter of the specimens was 47-50 mm and length was from 35 mm to 70 mm. Specimens were loaded to final rupture by the portable loading device developed. The result of split test shows that the tensile strength σ_{UT} differs only a little from the result obtained by other methods. In the case of other variables such as E, however, are significant differences, which do not allow practical use of measurements of E. This behavior can be explained by the growing influence of deformation of the devices frame on indirect measurements. Measusered relationship between loading force to deformation of Brazilian disc is showen in Fig. 2

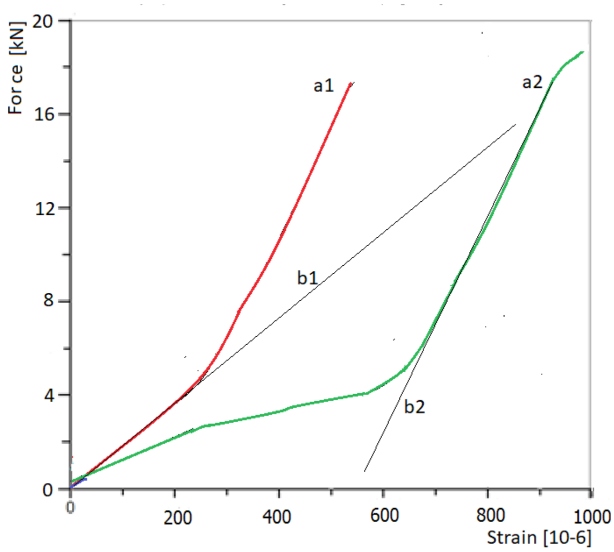

Fig. 2 Loading curves to the final rapture of sandstone a1 and limestone a2. The tangential lines b1 and b2 coresponds to linear part of loading curve.

The graph is contains two parts: a) the curves a1 and a2 which coresponds to situation, where the Brazilian disc was loaded to the final fracture; b) straight lines b1 and b2 which are coresponding to the theoretically linear region in the beginning of the test. This two lines are at a rough guess tangental to the curves a1 and a2, see Fig. 2. This was obtained for sandstone (curves numbered 1) and limestone (curves numbered 2).

5 Effect of anisotropy of stone

Since many rocks types are anisotropic (e.g metamorphic and sedimentary) the mechanical properties differ in different directions. Non-homogenity and presence of microcrascks caused different behavior under tensile and compressive conditions. In general, there are two kinds of elastic modulus: the compressive modulus E_C and tensile modulus. E_t. This effect was studied on three groups of measurements: a) The loading force is perpendicular to the sediment plane; b) tangential; c) loading force is rotated by 45 degree to the plane of sedimentation layer.

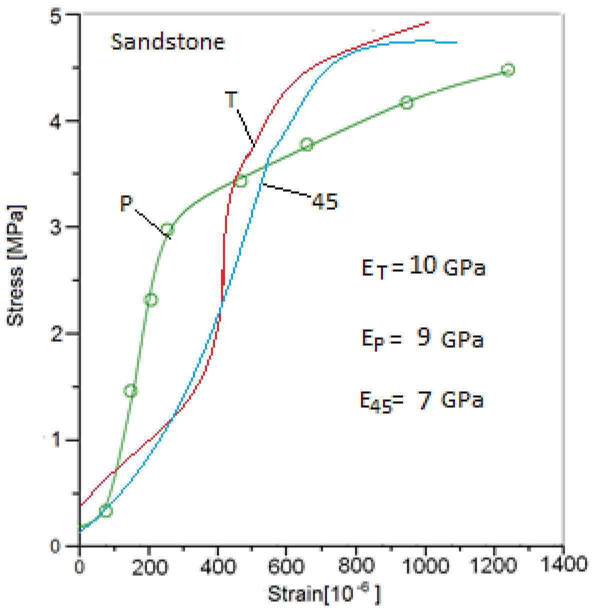

Fig. 3 Loading curves for concrete and determined elastic modules for different orientation of sample. The concrete sample was also rotated, though it is without sedimentation layers.

6 Results

In this paragraph are results of experiments realized during arrangement of this article. The results are shown in the Fig. 3, Fig. 4, Fig. 5 and Fig. 6. The experiments were realized on sandstone, limestone and marlite specimens. Also some experiments were realized on concrete specimens.

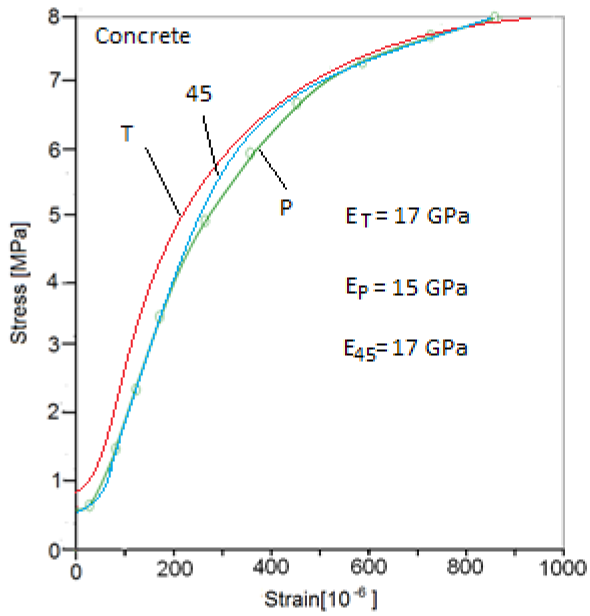

Fig. 4 Loading curves for sandstone and determined elastic modules for different orientation of sample.

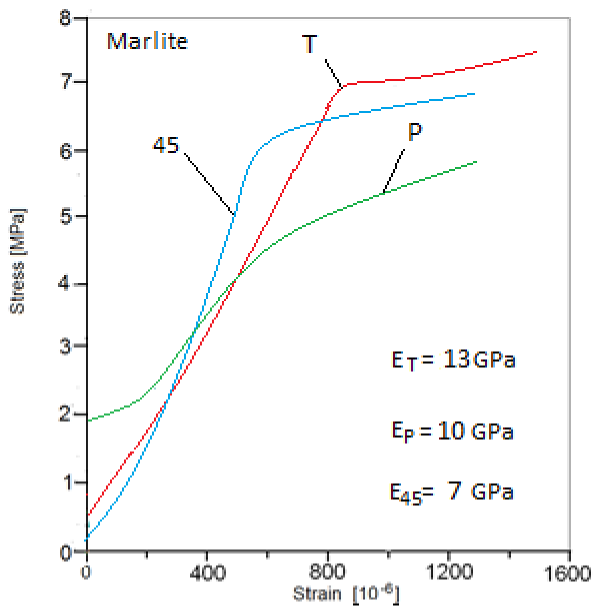

Fig. 5 Loading curves for marlite and determined elastic modules for different orientation of sample.

The concrete specimens were used for comparison, because concrete is isotropic material without sedimentation layers. In all graphs are three loading curves which are used to determine elastic modulus.

The elastic modulus was calculated for three different orientations described in previous paragraph. The curves and also the calculated values of elastic modulus are described by indexes: T – tangencial (The loading force is tangencial to the sediment plane); P – paralel; and 45 which means, that the loading force is rotated by 45 degree to the plane of sedimentation layer.

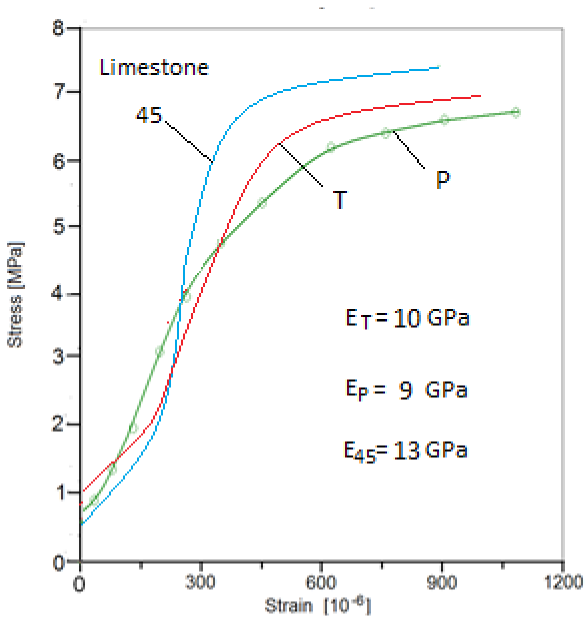

Fig. 6 Loading curves for limestone and determined elastic modules for different orientation of sample.

5 Conclusion

This article show clearly shows that the measurement device can be used for determination of elastic modulus from Brazilian test. Experiments show significant dependence on the sample orientation in all cases of material with sedimentation layers. The device is working properly, though the controller is based on the platform, which is not devout to the professional measurement, but for the schools.

Acknowledgment

This project was prepared by finantial support “Robotické stavebnice” 18/I zč SV 2127 - pracoviště 1440.

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